

EFFECT OF POT SOAK TIME ON CRAB CATCH IN THE BERING SEA AND ALEUTIAN ISLANDS



by

Peter G. van Tamelen

REGIONAL INFORMATION REPORT¹ NO. 5J01-18

Alaska Department of Fish and Game
Division of Commercial Fisheries
P.O. Box 25526
Juneau, Alaska 99802-5526

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ABSTRACT

The number of animals caught in a trap or pot is dependent upon the time the trap was immersed in the water or soak time. Several studies, both experimental and theoretical, have evaluated soak time effects on catch per pot of various species. The experimental studies are limited in replication and range of soak times with little or no attention given to temporal or spatial variation within or between species. Using observer data for the Bering Sea and Aleutian Island crab fisheries between 1997 and 1999, the total catches per pot of four crab species were determined over the observed range of soak times. Sample sizes were large, ranging from 401 to more than 8,000 pots per year. Snow crabs, *Chionoecetes opilio*, had the highest catch rates, averaging up to about 300 crabs per pot. The catch per pot of hair crabs, *Erimacrus isenbeckii*, was lowest at about 3 crabs per pot. Red and golden king crabs (*Paralithodes camtschaticus* and *Lithodes aequispinus*) had similar catch rates of about 30-60 per pot. Sublegal male and female crabs were rarely caught in the snow crab fishery, but formed large portions of the catch in the other fisheries. In the snow crab fishery, however, a large proportion legal crabs are discarded due to small size and poor condition. In all fisheries, the catch of discard crabs either decreased very slightly with longer soak times or did not vary with soak time. Data were fitted to a published catch-soak time model. Generally, there was a large amount of variation in the data and the model was not a particularly good predictor of catch. This variation may be due to the range of fishing techniques and behavior found in commercial fisheries. For most species, the catch-soak time curves varied between years, indicating temporal changes in patterns of catch within a species.

INTRODUCTION

In commercial pot fisheries, the catch per pot (CPP) is often used to index abundance as a management tool to meet harvest guidelines (Zheng et al. 1996). The CPP, however, is dependent upon pot immersion (soak) time and can also be influenced by other factors including local density of target species, the presence of other species, bait quality and quantity, tidal currents, time of day, gear design, and local topography (Miller 1979). The catch of non-legal individuals and unwanted species may also be related to soak time (Pengilly and Tracy 1998). Knowledge of the relationship between soak time and catch of target and non-target individuals would benefit managers by providing some insight into the relationship between pot surveys or harvest rates and actual abundance as well as aiding in estimating the catch of non-legal individuals. Fishers will also be interested to know soak time effects on legal and non-legal catches, so that they can alter their fishing behavior to maximize the catch of legal individuals and minimize discards and operating costs.

Both empirical and theoretical approaches have been used to investigate the effect of soak time on catches. Several studies attempted to experimentally test the effect of soak time on catch rates, but all suffer from limited experimental treatments and replicates (Miller 1979; Fogarty and Borden 1980; Boutillier 1985; Sloan and Robinson 1985; Somerton and Merritt 1986; Boutillier and Sloan 1987; Smith and Jamieson 1989; Pengilly and Tracy 1998). These experiments have between 4 and 7 soak time treatments with less than 50 replicates, except where commercial fishers performed the fishing (Fogarty and Borden 1980). Experimental soak times were mostly 1, 2, 3, or 4 days with only a few studies examining soak times of less than 24 hours when a large fraction of crabs enter a pot. An alternative approach was to use the log books from the fishers themselves, providing a higher sample size (Bennett and Brown 1979), but the analyzed soak times were limited to 1-5 days and data were from only 5 volunteer vessels. In addition, temporal and spatial variations are ignored in most studies. Most of these studies have shown that CPP is generally not linearly dependent upon soak time but tends to asymptote to some equilibrium value with long soak times. Some of the datasets indicate that catch may decline with longer soak times due to escape of individuals.

There have been numerous attempts to model the relationship between catch and soak time. Three types of models have been used to describe the catch per pot over time (Zhou and Shirley 1997b). Power function models are useful for short soak durations and are simple but do not incorporate any escape terms. Asymptotic catch models are widely used and assume that there is a maximum catch with infinitely long soak times. Finally, various models that incorporate declining catches have been proposed (Somerton and Merritt 1986; Zhou and Shirley 1997b). Because it is general and most of the previous models are special cases, one model is appealing (Zhou and Shirley 1997b). These models were generally derived from growth curves, stock-recruitment models, or other previously established but unrelated models, so the functional relationship between local density and capture rate is unclear. The data used to develop and test these models are mostly results of soak time experiments with limited treatment numbers and low replication. When there are many uncontrolled factors that can influence catch, such as

current speed, pot orientation, local density, and the presence of other species, large sample sizes are essential to adequately encompass the range of these random variables that would likely be encountered.

Most previous studies focused on total catch, but the proportion of sublegal and female crabs caught is also of interest to both managers and fishers. Handling mortality may be high for some of these fisheries, potentially jeopardizing the health of future stocks (Zhou and Shirley 1996; Kruse et al. 2000). If fewer unwanted crabs are caught and returned to the sea, handling effects should be minimized and stock health should increase. Longer soak times may allow sublegal crabs in the pot enough time to locate the escape vent and exit the trap (Pengilly and Tracy 1998), but this idea has not been thoroughly tested. The catch of unwanted crabs may also vary with crab species.

Large data sets of observations exist for commercial crab fisheries in western Alaska. Observers are required on commercial fishing vessels operating in the Bering Sea. Initially, observers insured compliance with regulations, but the data collected by observers has become the dominant focus and has been used for many research purposes (Moore et al. 2000). Many of the crab species have clumped distributions, and fishers will work areas where they have recently been successful. Thus, a majority of their pots will be set in areas likely to yield good catches. Therefore the data will be biased in favor of good fishing areas, but represent the conditions encountered during the fishing season. This study used the extensive observer database, that has sample sizes ranging from 400-8,000 pots for each fishery and year, over a three year period to evaluate the total catch, as well as the proportion of sublegal male and female crabs, of crab pots targeting various crab species over time.

METHODS

As part of the routine duties, mandatory observers in the Bering Sea and Aleutian Island crab fisheries randomly choose and sample the contents of pots. For each pot the location, date of recovery, soak time, and the number and sex of each crab species caught are recorded. In addition, the numbers of legal and sublegal males of the target species are recorded and whether these males were retained. Before 1997 soak times were recorded to the nearest day, but soak times declined dramatically with regulations controlling the total number of pots a vessel could fish and observers subsequently began recording soak times to the nearest hour.

For each observed pot, I calculated the total number of target species crabs caught and the proportion of sublegal males and females of that species. Non-target species were ignored. This was done for four fisheries including Aleutian Island golden king crab (*Lithodes aequispinus*), Bristol Bay red king crab (*Paralithodes camtschaticus*), Bering Sea snow crab (*Chionoecetes opilio*), and Bering Sea hair crab (*Erimacrus isenbeckii*). Data for Community Development Quotient fisheries and regular fisheries were combined. This study used data from 1997 to 1999 from all fisheries.

The proportion of vessels observed varied greatly between fisheries (Table 1). Both the golden king crab and hair crab fisheries had 100% coverage with 8-18 vessels participating in each fishery. The total coverage for snow crab and red king crab ranged from 5% to 12% with 226-281 vessels participating in each fishery. The number of vessels observed ranged from 8 to 31 for any particular year and fishery. In the fisheries that did not have 100% observer coverage, all catcher processor vessels were observed as well as a subsample of fishing vessels. For the red king crab fishery the selected fishing vessels were randomly chosen in 1997 and 1998, but volunteers in 1999. In the snow crab fishery, fishing vessels were only observed in 1999 and were all participating in the Community Development Quota program, and the coverage was randomly spread over almost all of the vessels. Due to lack of resources, snow crab vessels were not observed all of the time, but almost all vessels were observed some of the time.

The number of observations varied greatly between fisheries. The most pots, 8315, were observed in the golden king crab fishery in 1997, and the fewest pots, 401, were observed during the 1999 Bristol Bay red king crab fishery. Even with a low value of 401 pots, the sample size is large enough to make data presentation and analyses difficult. For this reason, all values for each soak time observed were averaged and regression analyses were done on the mean values for each soak time. The mean values were weighted by the number of observations for each soak time. Comparison of regression using all data and mean values weighted by sample size, yielded identical coefficients describing the best fit curve. Using the means rather than all data, however, resulted in higher values for r-squared because the data were not as scattered but lower ANOVA F-values because the sample sizes were much smaller.

Non-linear regression was used to analyze the total catch data. A previous model (Zhou and Shirley 1997b) has been proposed to relate catch to soak time. Their equation:

$$C_t = ab + a(t - b)e^{-ct}$$

was used for the non-linear regression of the catch for soak time, C_t , versus soak time, t . The coefficients a , b , and c are parameters to be estimated. For the percent of sublegal and females in the pot, linear regressions on mean values weighted by number of observations were used.

RESULTS

Aleutian Island Golden King Crab

For the Aleutian Island golden king crab fishery, soak times varied between 5 and 1920 hours (=80 Days) with an average of about 160 hours (Figure 1). The distribution of soak times remained constant over all years examined. The total number of pots observed for this fishery was high, ranging from 4903 in 1998 to more than 8,000 in 1997 and 1999.

In all three years the Zhou-Shirley model accounted for significant amounts of data variation (Figure 2, Table 2). The model fit better for short soak times, less than about 100 hours, but the data became more variable with longer soak times. There was no apparent decline in total catch with longer soak times. The fitted parameters were about equal for all three years although the asymptotic catch ranged from about 20 to more than 40 crabs per pot.

The proportion of sublegal crabs declined significantly with longer soak times in all 3 years, but the decline was slight (Figure 3, Table 3). The regression slopes ranged from -0.0002 to -0.0004 indicating that 0.02-0.04% of crabs were lost per soak hour. The proportion of female crabs also declined slightly in 2 of the 3 years with rates of decline similar to that for sublegal males (Figure 4, Table 3). About one third of the caught crabs were females and another third were sublegal males.

Bristol Bay Red King Crab

The soak times for the Bristol Bay red king crab fishery varied from 5 to 146 hours and averaged between 22-35 hours (Figure 5). Soak times were shorter in 1997 compared to 1998 and 1999. The total number of pots observed was about 550 in 1997 and 1998 and dropped to 401 in 1999.

The Zhou-Shirley model described the data poorly with only one year, 1999, having a significant fit (Figure 6, Table 2). In all years including 1999 there was a large amount of variation in the data and the fitted curves were poor predictors of catch using these average values. The fitted curves for 1997 and 1998 were similar, increasing rapidly to a maximum value and then decreasing slightly to asymptote at 17 and 65 crabs per pot. The fitted model was different in 1999. Over the soak times observed, the curve did not peak and showed a continually increasing catch but increased more slowly than in the previous years.

In 1997 and 1998, there was a significant decrease in the proportion of sublegal crabs with increasing soak time, but the relationship was not significant in 1999 (Figure 7, Table 3). The slope of the significant regressions was -0.005 and -0.0023 for 1997 and 1998; so for each hour of soak time, the average decrease in percent of sublegal crabs was 0.5% and 0.23%. The percent of sublegal crabs initially caught in pot varied from about 30 to 60%. Few females were caught in 1997 and 1999 and there was no significant relationship between the percent of females caught and soak time (Figure 8). In 1998 when about 25% of the initially caught crabs were female, there was a significant decline in percent of females in the pot over time (slope=-0.0023).

Bering Sea Snow Crab

The average soak time in the Bering Sea Snow Crab fishery was about 48 hours and ranged from 2 to 500 hours (Figure 9). The number of pots sampled increased from 1703 to 2269 between 1997 and 1999.

For all three years, the fitted Zhou-Shirley model increased to an asymptote ranging from 254 to 342 crabs per pot with no subsequent decline (Figure 10, Table 2). Compared to the king crab species, the catch per pot lift was large. The model fit the data well with shorter soak times, less than about 50 hours, but with longer soak times there was more variation in the catch per pot. The fitted parameters were about the same for all three years.

The catch of both sublegal and female crabs was low, rarely exceeding 10% and generally averaging around 1% or less (Figures 11 and 12). In 1997 there was a significant decrease in the percent of sublegal male crabs with increasing soak times, but the decrease was only 0.01% per hour of soak time (Table 3). Fewer female crabs, less than 0.5%, were caught than sublegal male crabs, between 0.9 and 3%.

Although there were few sublegal and female snow crabs caught, a fairly high proportion of legal males were discarded due to low value to the fishers (Figure 13). These crabs were above legal size but below the size acceptable by processors. Crabs with very old shells and few legs were also discarded even though they could be kept legally. About a third of the total catch was discarded due to small size and poor condition. The proportion of discarded legal male crabs remained constant in 1999 but decreased slightly in 1997 and 1998 at a rate varying between 0.04 to 0.11% per soak hour (Table 3).

Bering Sea Hair Crab

The average soak time of the Bering Sea hair crab fishery ranged from 25 to 37 hours (Figure 14). Soak times varied from 4 to 228 hours. The number of pots sampled declined from 4430 to 1902 between 1997 and 1999.

In two of the three years the Zhou-Shirley model fit the data reasonably well indicated by significant regressions, and the fitted parameters were similar in all three years (Figure 15, Table 2). The fitted model increased rapidly to a peak and then declined slightly to asymptote to between 1.8 and 2.9 crabs per pot.

Neither the proportion of sublegal males nor females declined significantly with soak time (Figures 16 and 17, Table 3). In fact, in 1997 the percent of female crabs significantly increased with soak time. The average proportion of sublegal males caught ranged from just less than 5% to more than 10%. The proportion of females caught varied between 2 and 15% over the three years. In 1997, up to about 30% of crabs caught were female. The percent of females was about 15% and 4% in 1998 and 1999.

DISCUSSION

The CCP was highly variable and the Zhou-Shirley model was generally not successful at explaining this variation. Although 9 of the 12 non-linear regressions were significant, the graphs show large departures from the best fit Zhou-Shirley model using the mean CCP for each hour. The main reason for the observed significant relationships is the

large sample sizes rather than a good fit to the data. In the snow crab fishery, however, the model fit the data well for soak times of 48 hours or less, but longer soak times produced more variable results. Similarly, for soak times less than about 24 hours in the hair and red king crab fisheries in 1999, the model fit the observed data reasonably well. Thus, soak time can be a good predictor of catch per pot for shorter soak times in some Bering Sea fisheries and years. For longer soak times and other fisheries, such as golden king crab and most years of red king crab, soak time does not predict CCP well. There are numerous other factors that can influence CCP.

The gear used by fishers can certainly affect the catch. For the king and snow crab fisheries, pots can either be rectangular with the tunnel eye opening on vertical panels or pots can have a rectangular base and taper to a horizontal opening. In Southeast Alaska, ADF&G surveys use the latter type because they tend to have more consistent and slightly higher catch rates. In the Bering Sea, fishers appear to use the non-tapering pots because they are easier to work and stack more solidly. The use of both kinds of pots during a fishery can lead to larger variation in data.

The fishing tactics used by fishers may have influenced the results of this study. The goal of fishers is to catch as many legal crabs as possible with the least amount of effort and not to randomly sample the population. If crabs show any appreciably clumped distribution, then fishers will certainly oversample areas of high abundance, leading to higher catch rates and total catches per pot compared to a random or systematic sampling scheme. With a limited number of pots and fishing seasons lasting less than 6 days, as occurs in the Bristol Bay red king crab fishery, fishers may not only tend to set pots in areas of high abundance but also pull those pots more frequently. Thus, pots that are doing well may have shorter soak times compared to pots in less desirable locations, and lower catches would be associated with longer soak times, leading to an apparent decline in catch with longer soak times. In this way, catch-soak time curves generated from commercial fishing data can reflect both crab distribution and crab catch over time. This may apply particularly to Bristol Bay red king crabs and Bering Sea hair crabs that have short seasons of 4-5 days and 15-38 days. These are the only two fisheries investigated that had declines in catch with increased soak time. Additionally, if the crabs are segregated based upon size or sex, then fishers will focus on areas where they are likely to catch legal crabs to reduce their bycatch of unwanted crabs. On the other hand, if crab distribution is random or even, then fishers will not be able to target areas of high abundance or legal crabs and fishing effort can be considered unbiased.

For Dungeness crab, the catch rate has been shown to increase when bait is openly suspended in the pot as opposed to contained within a perforated plastic jar (Miller 1979), and some Alaskan fishers use this technique (personal observation). Fishing techniques, including baiting practices and gear design, vary between fishers and may account for some of the variation in the data. Because this study sampled all or a presumably unbiased subset of the fishers, the conclusions drawn here are applicable over the range of behaviors and techniques used by the fishing fleet.

Other factors may influence the catch of crabs in pots. With higher densities, more crabs should be caught per pot (Miller 1975). At least for Dungeness crab,

however, the total catch is limited by the size of the pot and number of crabs present in the pot (Miller 1979). For most crab species studied here, the effect of within pot intra- and interspecific interactions on crab entry rate is unknown, but is believed to be less than that reported for Dungeness crabs due to the large size of pots used (about 2.0 x 2.0 x 0.8 m). The exception to this may be hair crab where pots are limited to 1.22 m in any dimension.

A number of factors potentially influencing catch were assumed to vary randomly in this study. The position of gear relative to the prevailing bottom current may influence the fishing performance of square pots. When an entry tunnel is oriented downstream, entry into the pot by crabs following the odor plume is facilitated, but when a foraging crab encounters an impassable mesh barrier, entry time is increased and rate of entry is reduced (Zhou and Shirley 1997a). Current velocity also effects navigation by crabs (Finelli et al. 2000). In strong currents, the odor plume will extend farther downstream but be narrower, increasing the time it takes for crabs to walk to the pot (Jernakoff and Phillips 1988; Finelli et al. 1999; Finelli et al. 2000). This study ignored the effect of tidal stage, spring or neap, but used data gathered over all tidal phases. Topography may influence catch rates by affecting the shape and concentration of the odor plume (Jernakoff and Phillips 1988). If a pot lands on a ledge, even a small one, and the current flows over the edge, then the odor plume may never get close enough to the substrate for crab detection. The large sample sizes used in this study should encompass the range of these factors experienced during fisheries.

The catch of king crabs varied dramatically between years. For golden king crab, the asymptotic number of crabs caught in a pot in 1998 was about twice that in 1999, and the asymptotic catch rate of red king crab also varied markedly between years. Although the shapes of the catch-soak time curves were similar in all three years for golden king crab, the shapes were very different for red king crab. Variations in the shape of catch-soak time curves were also observed among other seasons in Bristol Bay red king crab (Briand et al. 2001). It appears that there may be fundamental year-to-year differences in king crab behavior or population size resulting in different patterns of catch. The reasons for this temporal variation are not known at this time, but crab behavior may vary from year to year. Red king crabs are known to migrate and can also be highly clumped. The degree of migration and aggregation can easily influence the rate of capture and the asymptotic number of crabs caught. If crabs are highly aggregated and not migrating, then pots placed near aggregations would catch crabs rapidly due to high local density, but then would asymptote to a constant level if migration is low. On the other hand, if crabs are migrating and evenly dispersed, then initial catches would be low, but would constantly increase due to continuous supply of new migrants and asymptote at a higher level than the clumped, non-migrating population.

Most pot surveys use a fixed soak time and models have been developed to correct catches for soak times that differ from the target soak time (Somerton and Merritt 1986). Using a fixed soak time, however, can potentially lead to different relative abundances of crab populations at different times or places dependent upon the soak time used. For example, the fitted parameters from the Bristol Bay red king crab yielded very different

catch-soak time curves (Figure 18). If these populations were compared with a pot survey, the results would depend upon the soak time used in the survey. The relative abundance in 1997 would appear greater than 1999 with 24 hour soak times, but if 96 hour soak times were used, the opposite would be concluded. Similar interpretations can be made for Bering Sea snow and hair crab data.

For all the species studied here, there was little evidence that increased soak times resulted in substantial declines of discard crabs (Table 3). For all king crabs, a large proportion of sublegal and female crabs were caught (between 20 and 60%), but the proportion of these crabs decreased only slightly, although significantly in most cases, with longer soak times at a rate ranging from 0 to 0.5% per hour. Even if the maximum rate of decrease of 0.5% per hour is applied, then increasing the soak time from 24 to 36 hours results in the capture of only 6 fewer discard crabs with a total catch of 50 crabs. Increased soak times for snow and hair crabs did not result in fewer discard crabs. In the case of snow crabs, sublegal and female crabs, which are smaller than the males, may enter the pots but then escape readily. Even if the discarded legal snow crabs are examined, those crabs between 79 and 102 mm CW, there were only slight decreases in catch of these crabs with longer soak times even though the escape rings allow these crabs to exit the pots. The more streamlined morphology of snow crabs relative to that of king crabs may allow smaller, unwanted snow crabs to escape readily, spending little time in the pot, resulting in lower initial catch rates. Pots in the hair crab fishery are not required to have escape rings or larger stretch mesh to allow smaller crabs to escape, and thus the proportion of sublegal crabs should not decline with longer soak times.

If fishing tactics or any of the other factors discussed above had relatively large effects on the results of this study, then an experimental study done in the same area at the same time should have results that differ from this study. In 1997 an experimental study was carried out in Bristol Bay (Pengilly and Tracy 1998). The pots were soaked for 12, 24, or 72 hours and the abundance of legal male, sub-legal male, and female crabs in each pot were recorded (data presented in Figures 6 and 7). The total catch for the three experimental soak times were essentially identical to those obtained from the commercial fishing data, suggesting that the factors discussed above have little impact on the catch-soak time curves. From this comparison of experimental to fishery fleet observation data, it is clear that both methods yielded similar results. Although the catch per pot of both legal and nonlegal crabs increased with soak time, the ratio of nonlegal to legal crabs decreased (Pengilly and Tracy 1998). In the experimental study about 65-70% of the crabs caught with short soak times were nonlegal and this value declined to about 57% for 72 hour soak times, corresponding to a rate of decrease of about 0.2% per hour. This rate of decline is slightly less than those calculated for 1997 here but is similar to other years for red king crab. The proportion of nonlegal crabs, however, caught in the experimental study was substantially greater, 57-70%, than those caught during the commercial fishery, 15-40%, indicating that fishers successfully target legal crabs. Targeting legal male crabs appears to be more effective than increasing soak time to decrease bycatch for Bristol Bay red king crabs.

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Table 1. The total number of vessels, observer coverage, and season length for the four fisheries for both regular and CDQ seasons. NA indicates data is not applicable or available.

Fishery	Year	Regular Season			CDQ Season		
		Total Vessels	Coverage (%)	Season Length (d)	Total Vessels	Coverage (%)	Season Length (d)
Golden King	1997	18	100	364	NA	NA	NA
	1998	15	100	121	NA	NA	NA
	1999	16	100	365	NA	NA	NA
Red King	1997	256	7.4	4	NA	NA	NA
	1998	274	7.7	5	7	100	17
	1999	257	3.5	5	10	100	17
Snow	1997	226	6.2	65	NA	NA	NA
	1998	229	5.2	64	NA	NA	NA
	1999	241	4.1	66	23	91.3	92
Hair	1997	16	100	24	NA	NA	NA
	1998	11	100	15	NA	NA	NA
	1999	8	100	38	NA	NA	NA

Table 2. ANOVA results of the non-linear regressions of catch over soak time. The F/p column gives both the F-value and the p-value.

Fishery	1997			1998			1999		
	df	MS	F/p	df	MS	F/p	df	MS	F/p
Golden King	2	73278.1	27.05	2	63352.4	17.60	2	40648.4	23.57
	361	2709.1	<0.0001	311	3598.7	<0.0001	453	1724.5	<0.0001
	363	3097.9		313	3980.5		455	1895.6	
Red King	2	60.21	0.0263	2	2012.6	0.3015	2	25679.0	23.70
	44	2287.7	0.9740	54	6674.6	0.7409	49	1083.5	<0.0001
	46	2190.9		56	6508.1		51	2048.1	
Snow	2	2303905.8	31.91	2	2356168.9	44.24	2	1333591.1	55.89
	125	72208.5	<0.0001	154	53254.8	<0.0001	148	23859.4	<0.0001
	127	107353.3		156	82779.4		150	41322.5	
Hair	2	26.87	1.17	2	74.25	3.4776	2	53.60	7.2128
	76	22.92	0.3152	54	21.35	0.0380	68	7.43	0.0014
	78	23.02		56	23.24		70	8.75	

Table 3. The intercept and slope of linear regressions of percent of sublegal male (sublegal) and female caught on soak time for all fisheries and years examined. In addition, the data for discard crabs in the snow crab fishery are also given. The intercept indicates the percent of all crabs caught that were in the category, and the slope indicates the rate of change of the percent of crabs caught. Slopes that were statistically different ($p < 0.05$) from 0 are in bold.

Species	Type	1997		1998		1999	
		Intercept (%)	Slope (%/hr)	Intercept (%)	Slope (%/hr)	Intercept (%)	Slope (%/hr)
Golden King	Sublegal	34.3	-0.02	43.8	-0.04	34.9	-0.02
	Female	33.1	-0.02	21.7	0.00	29.2	-0.01
Red King	Sublegal	40.8	-0.50	56.2	-0.23	29.0	-0.12
	Female	6.2	-0.13	26.7	-0.23	1.6	-0.03
Snow	Sublegal	2.6	-0.01	2.3	-0.00	0.9	0.00
	Female	0.1	-0.00	0.1	-0.00	3.6	-0.03
	Discard	36.3	-0.04	26.9	-0.11	30.7	-0.02
Hair	Sublegal	4.8	0.01	10.4	-0.01	6.8	-0.01
	Female	0.2	0.14	15.4	0.01	3.6	0.03

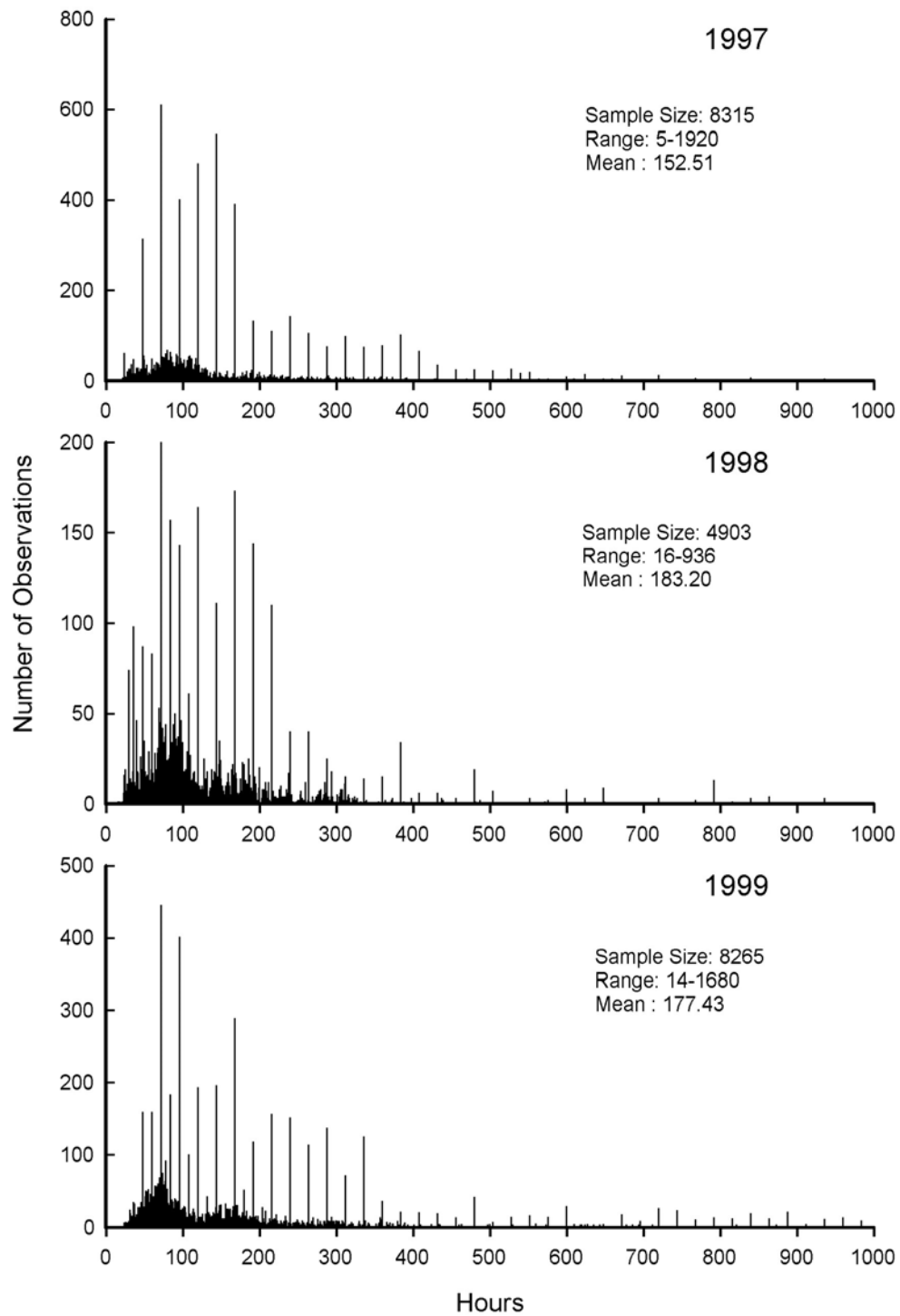


Figure 1. The number of pots observed for various soak times in the Aleutian Island golden king crab fishery for 1996, 1997, and 1998. The sample size, range, and mean are also given for each year.

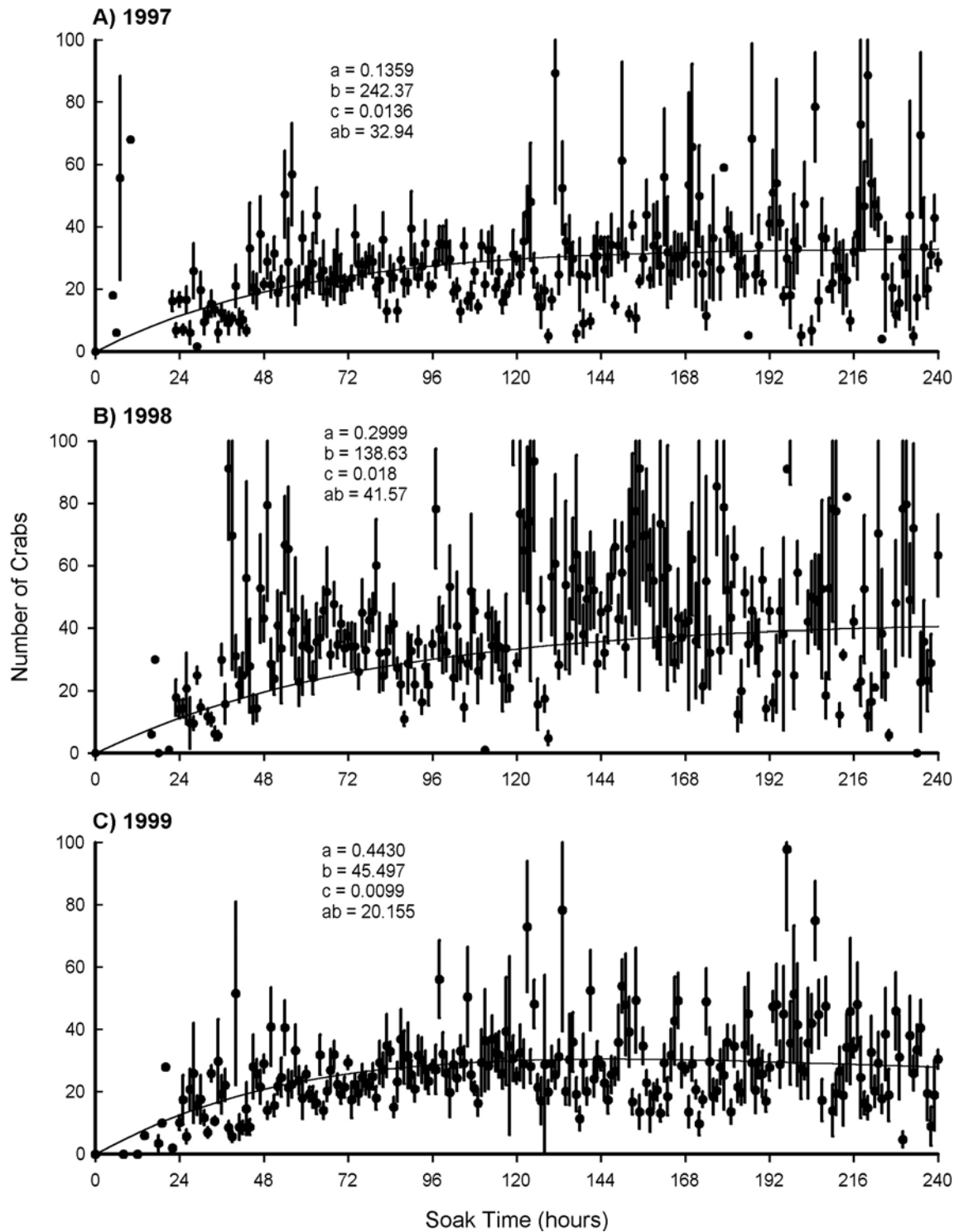


Figure 2. The mean (\pm standard error) total catch per pot of golden king crabs with various soak times for 1997 (A), 1998 (B), and 1999 (C). The fitted Zhou-Shirley model parameters are given for each year.

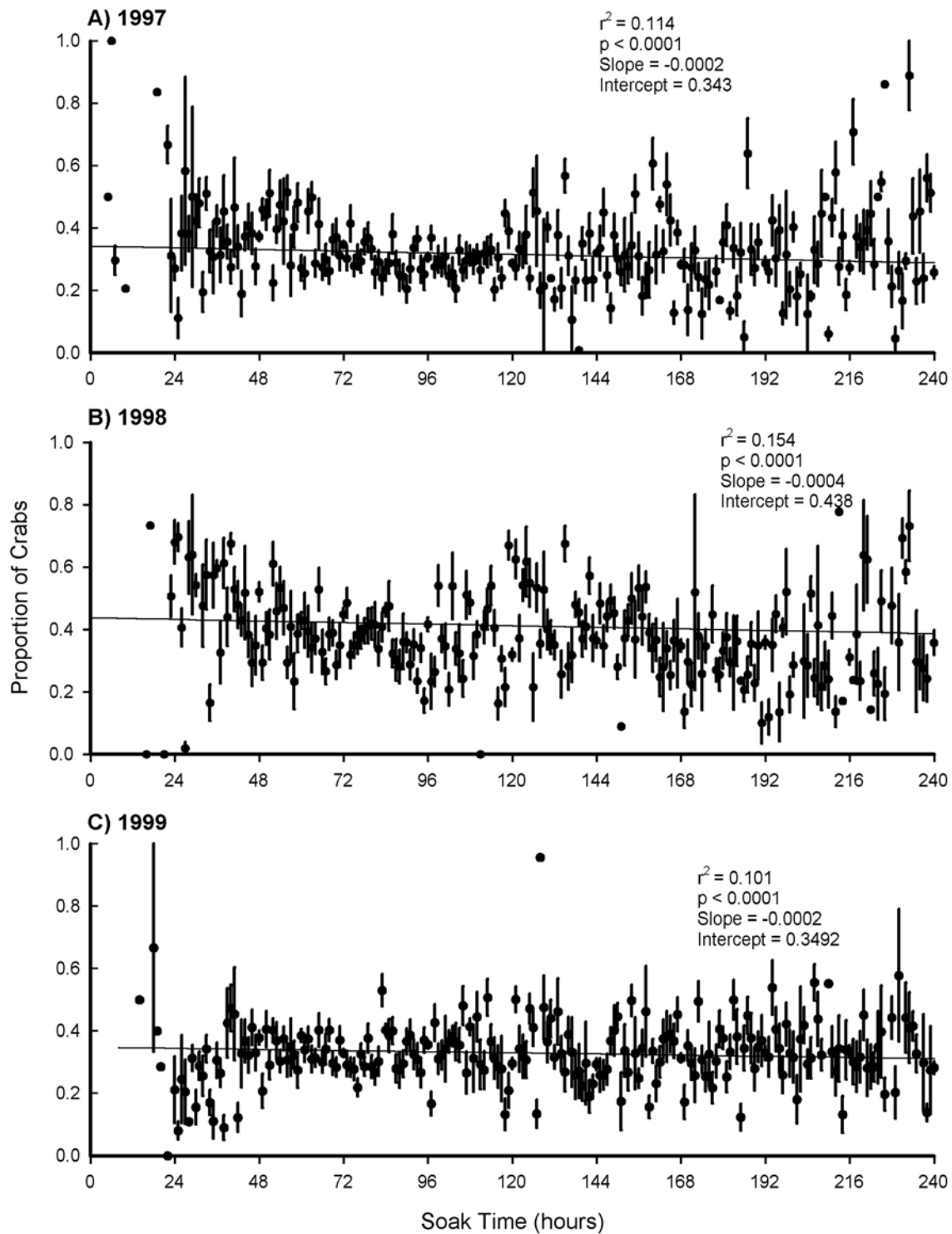


Figure 3. The mean (\pm standard error) proportion of golden king crab sublegal males in pots with various soak times for 1997 (A), 1998 (B), and 1999 (C). The r^2 value, p-value, slope, and intercept are given for each year.

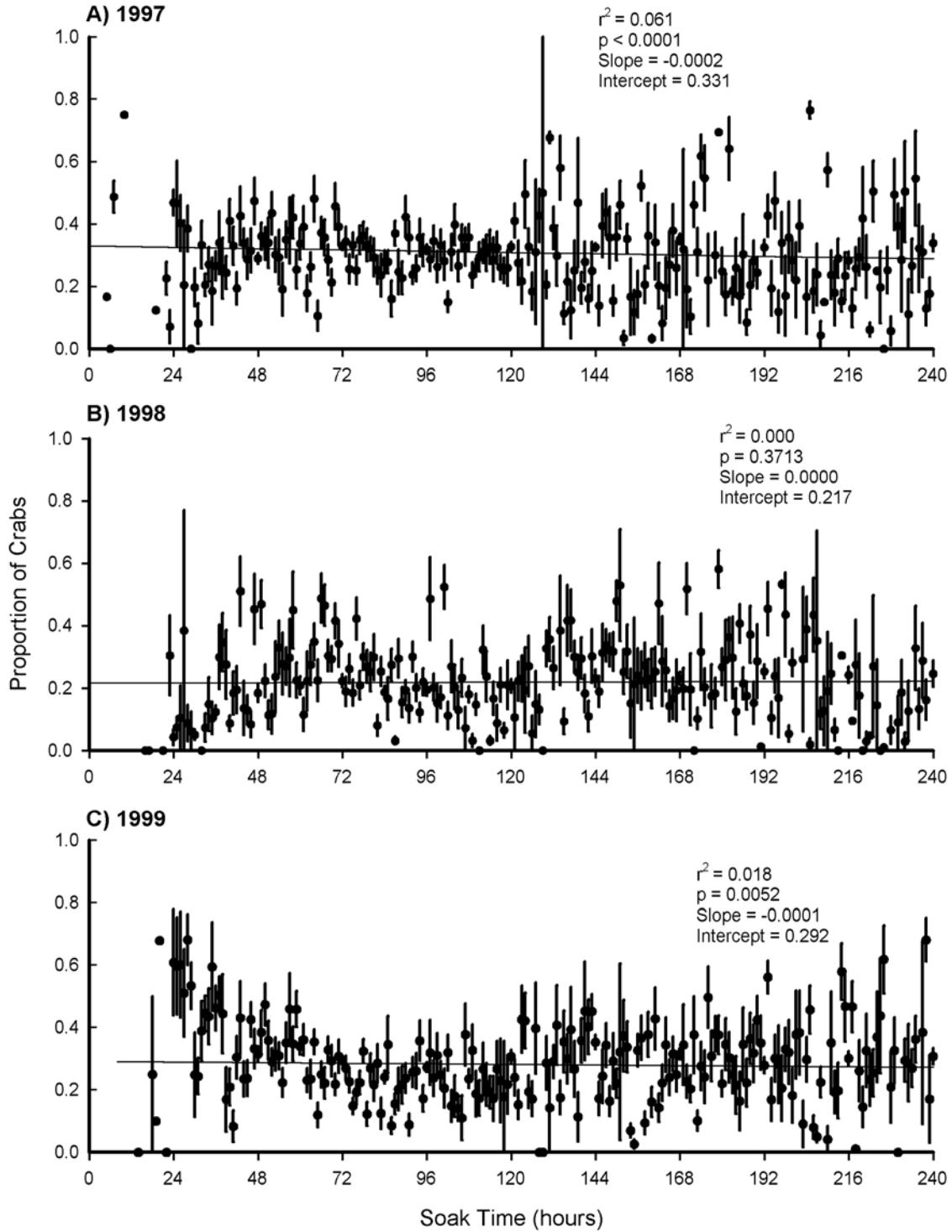


Figure 4. The mean (\pm standard error) proportion of golden king crab females in pots with various soak times for 1997 (A), 1998 (B), and 1999 (C). The r^2 value, p-value, slope, and intercept are given for each year.

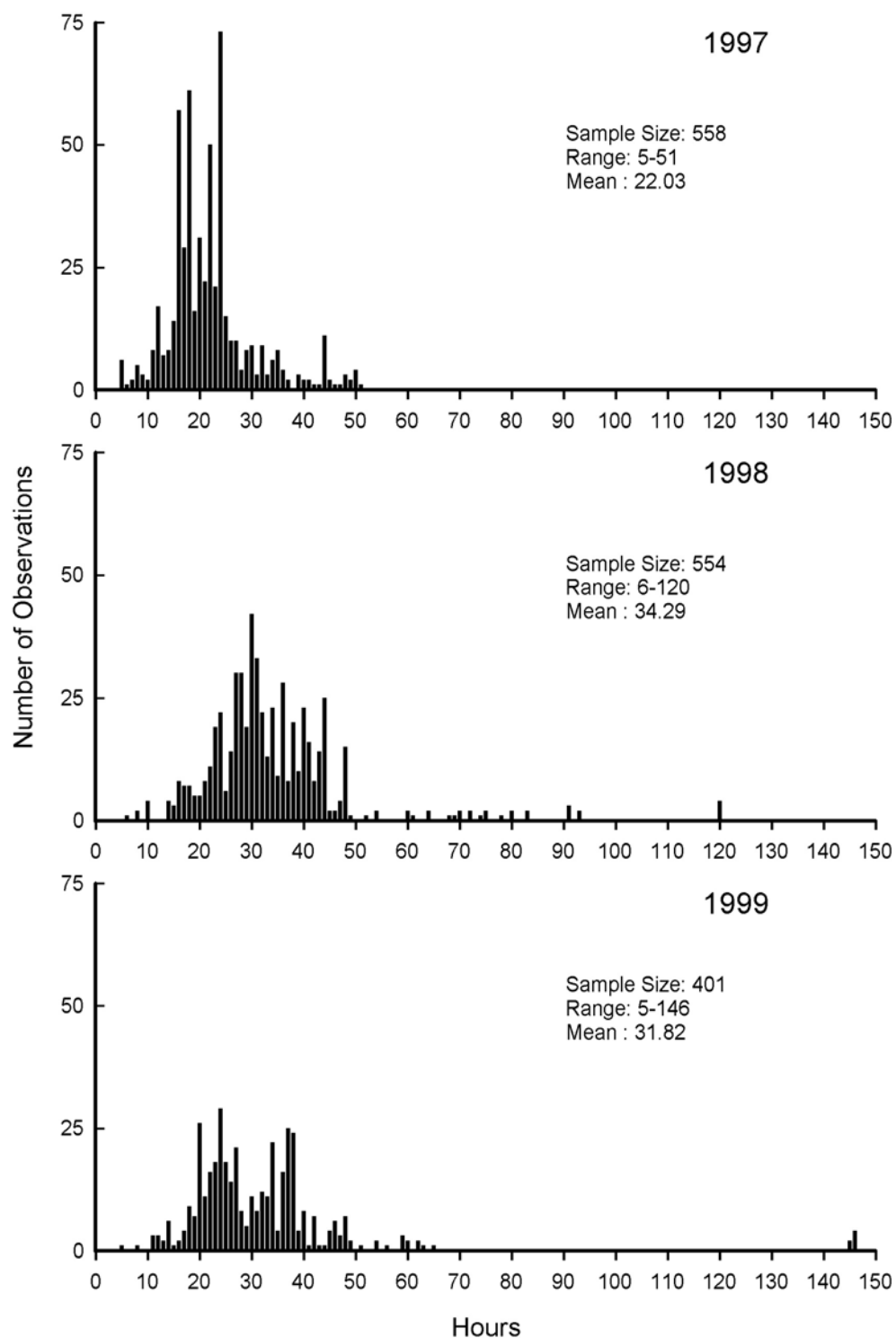


Figure 5. The number of pots observed for various soak times in the Bristol Bay red king crab fishery for 1997, 1998, and 1999. The sample size, range, and mean are also given for each year.

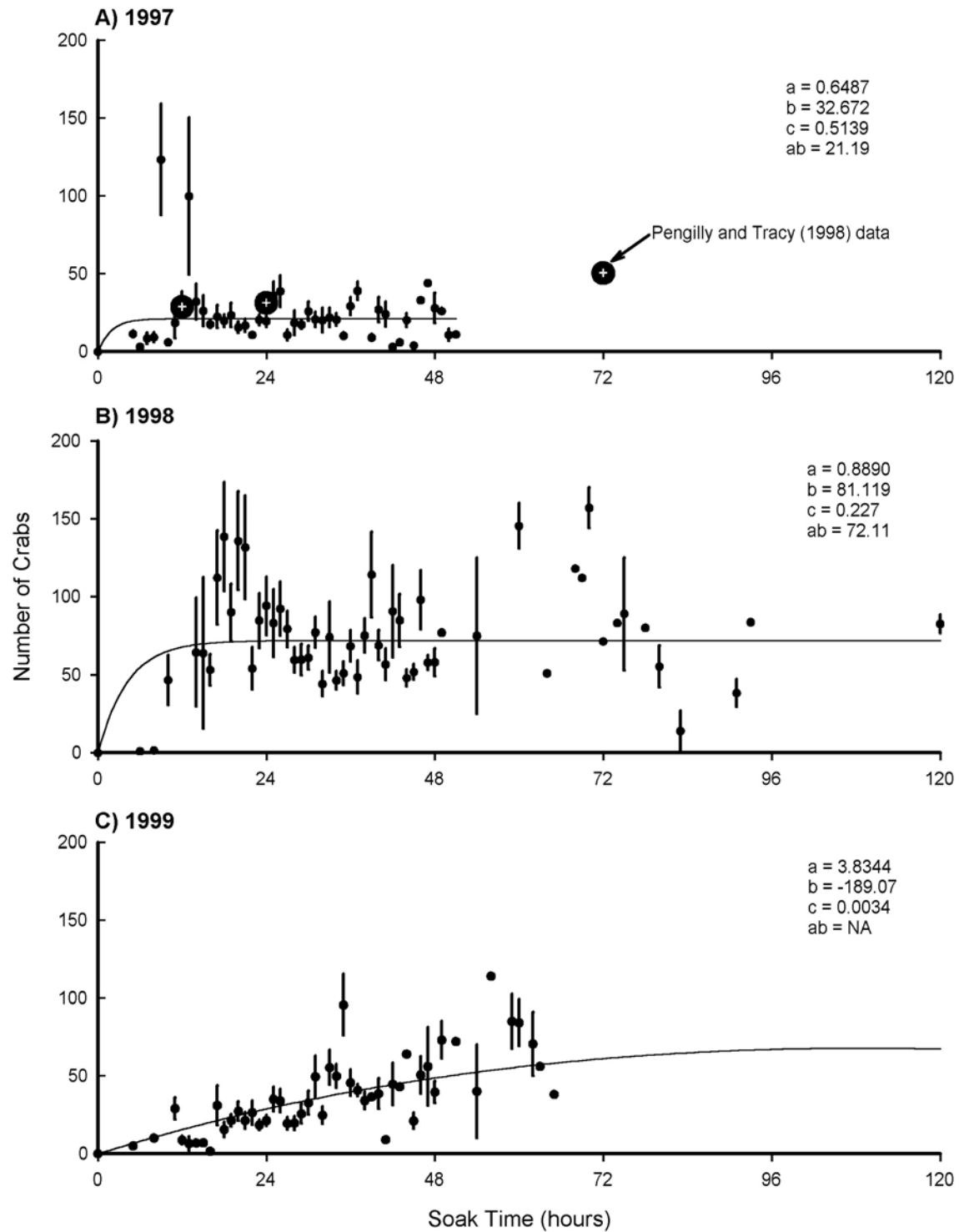


Figure 6. The mean (\pm standard error) total catch per pot of red king crabs with various soak times for 1997 (A), 1998 (B), and 1999 (C). The fitted Zhou-Shirley model parameters are given for each year. The total catch data from Pengilly and Tracy (1998) are also plotted for comparison.

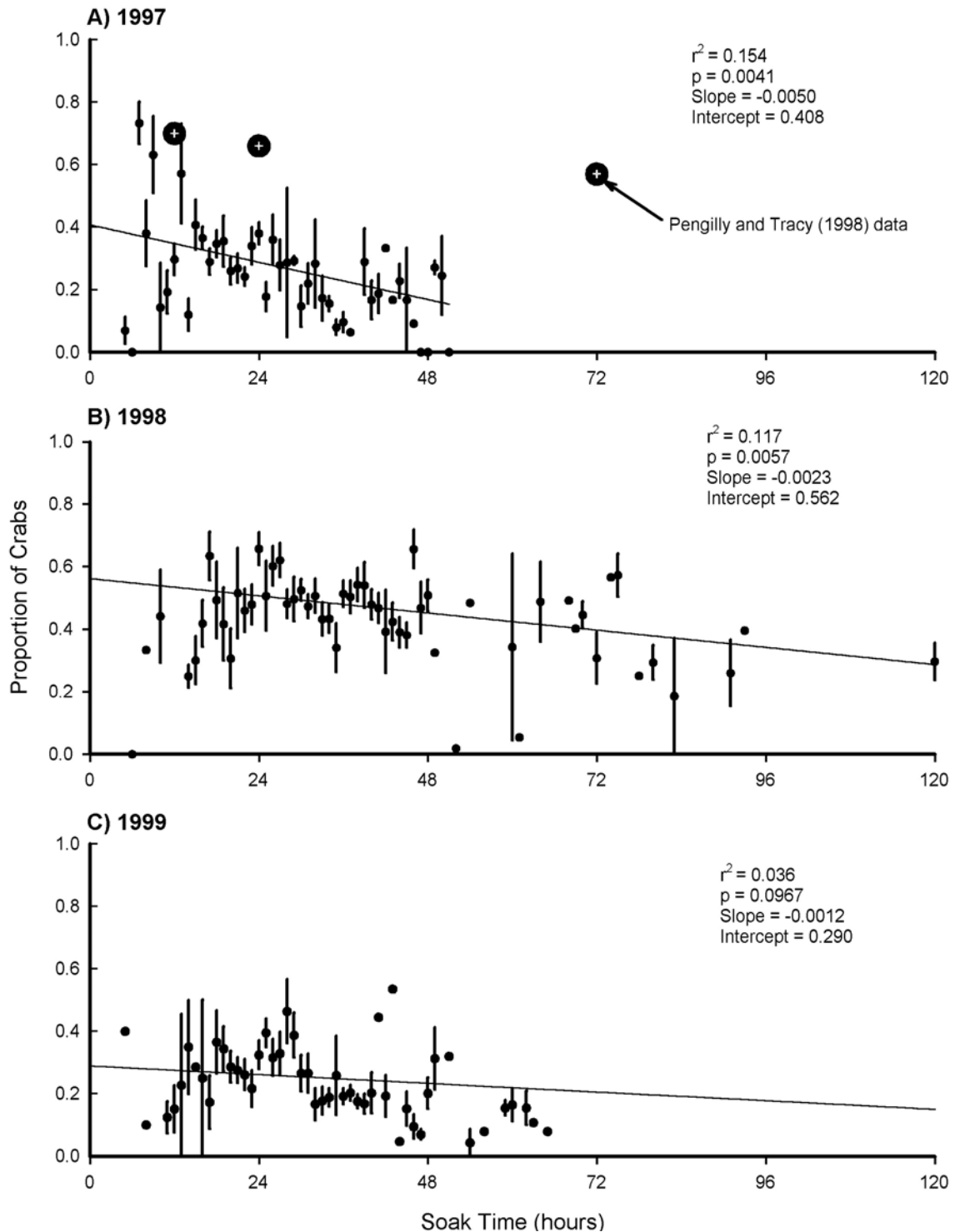


Figure 7. The mean (\pm standard error) proportion of red king crab sublegal males in pots with various soak times for 1997 (A), 1998 (B), and 1999 (C). The r^2 value, p-value, slope, and intercept are given for each year. The percent of sublegal crabs from Pengilly and Tracy (1998) are also plotted for comparison.

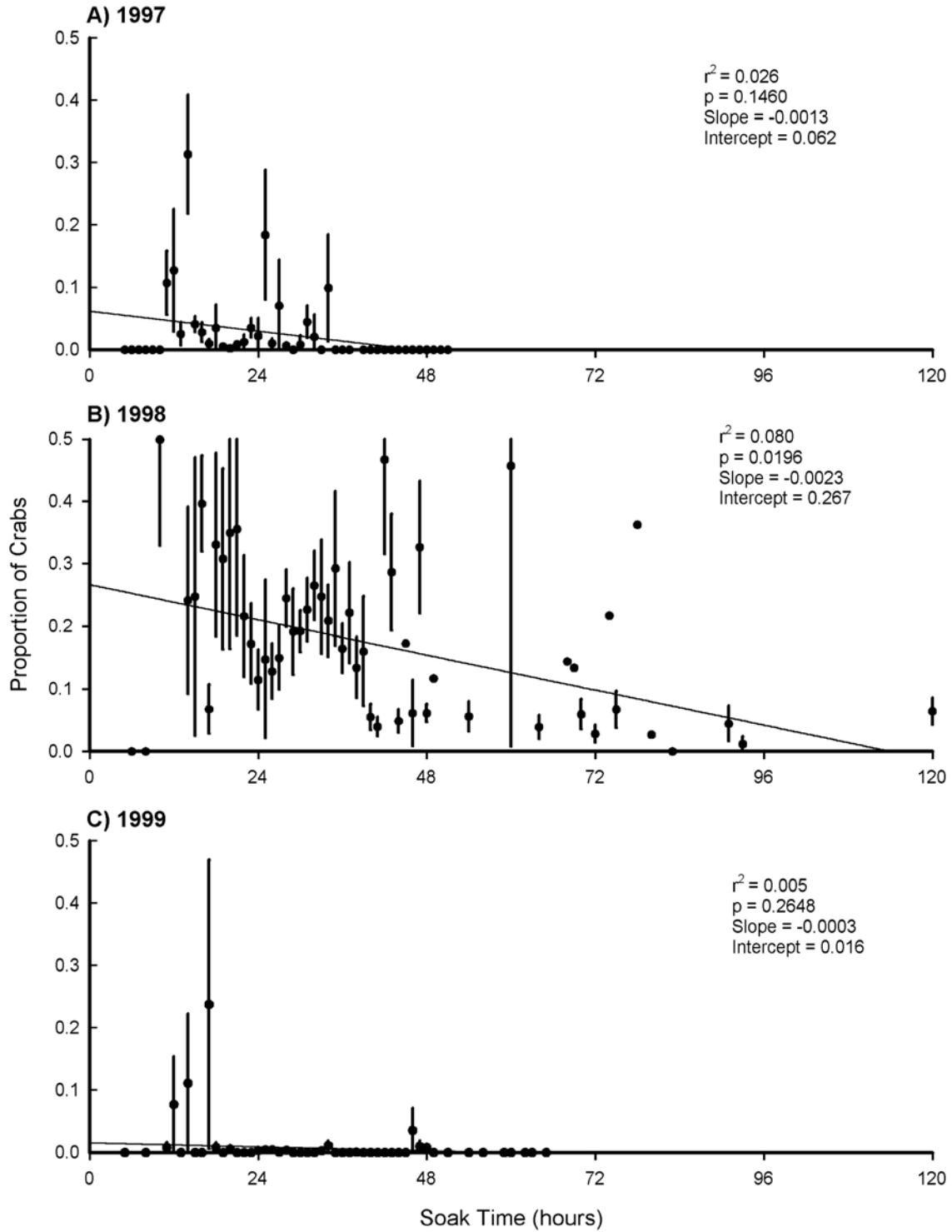


Figure 8. The mean (\pm standard error) proportion of red king crab females in pots with various soak times for 1997 (A), 1998 (B), and 1999 (C). The r^2 value, p-value, slope, and intercept are given for each year.

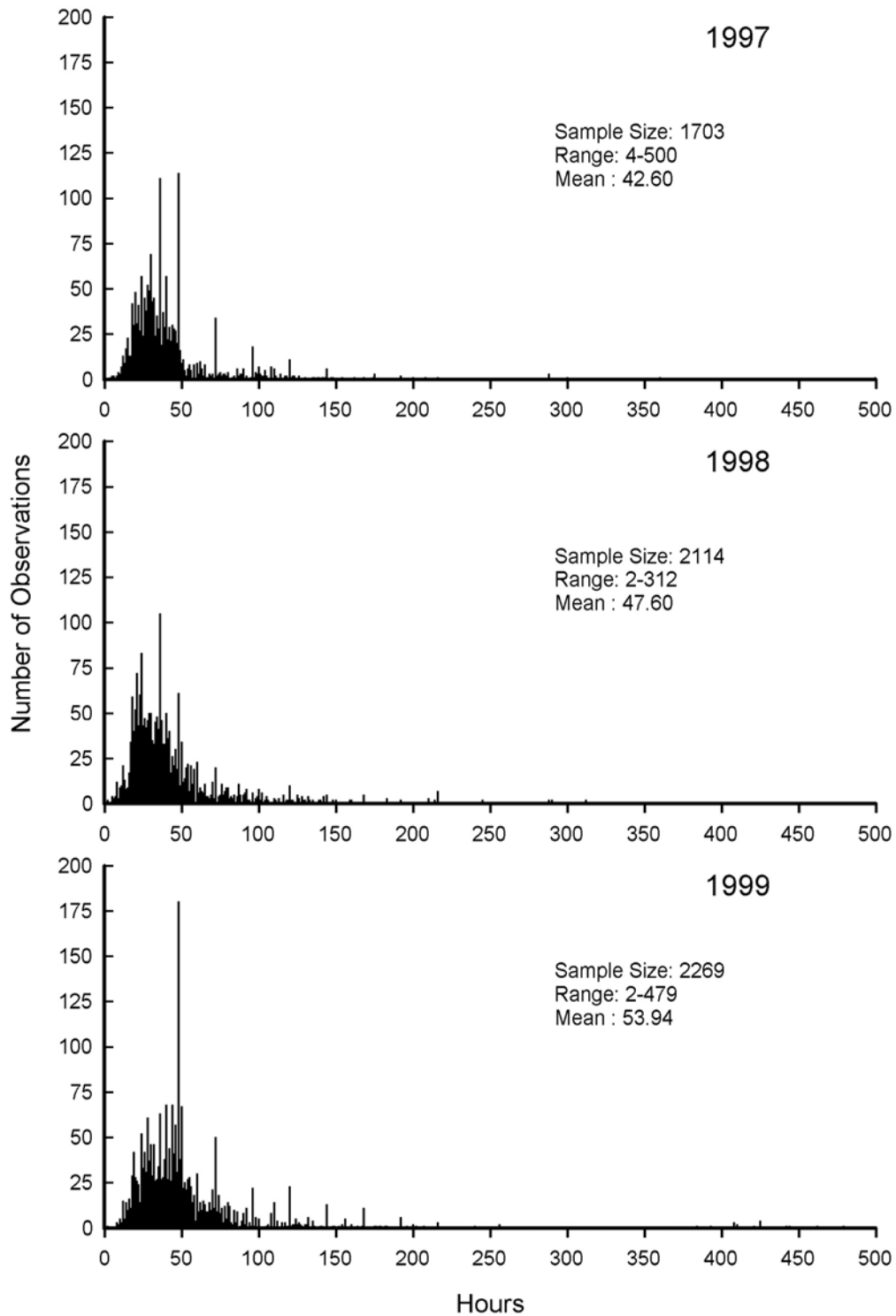


Figure 9. The number of pots observed for various soak times in the Bering Sea snow crab fishery for 1997, 1998, and 1999. The sample size, range, and mean are also given for each year.

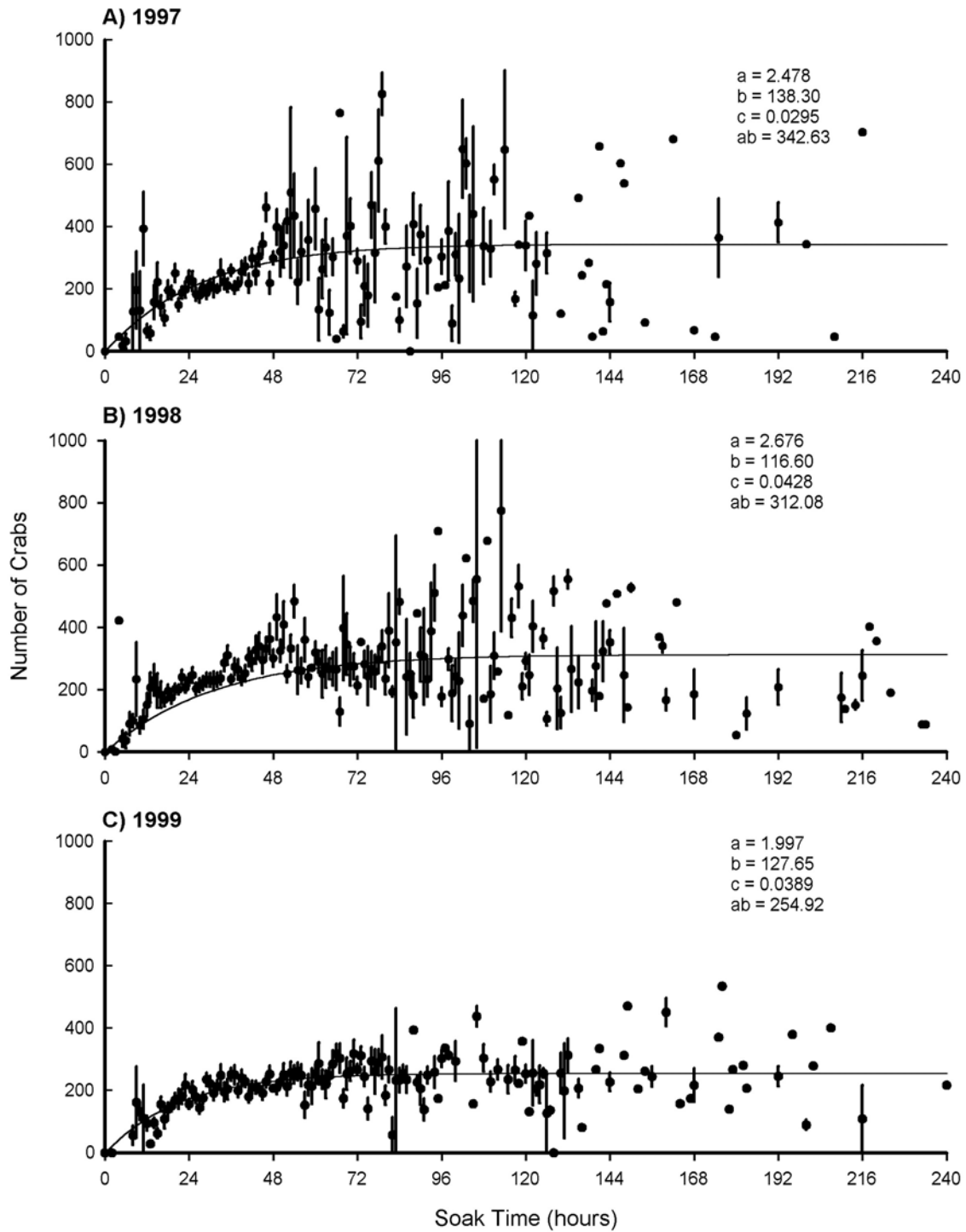


Figure 10. The mean (\pm standard error) total catch per pot of snow crabs with various soak times for 1997 (A), 1998 (B), and 1999 (C). The fitted Zhou-Shirley model parameters are given for each year.

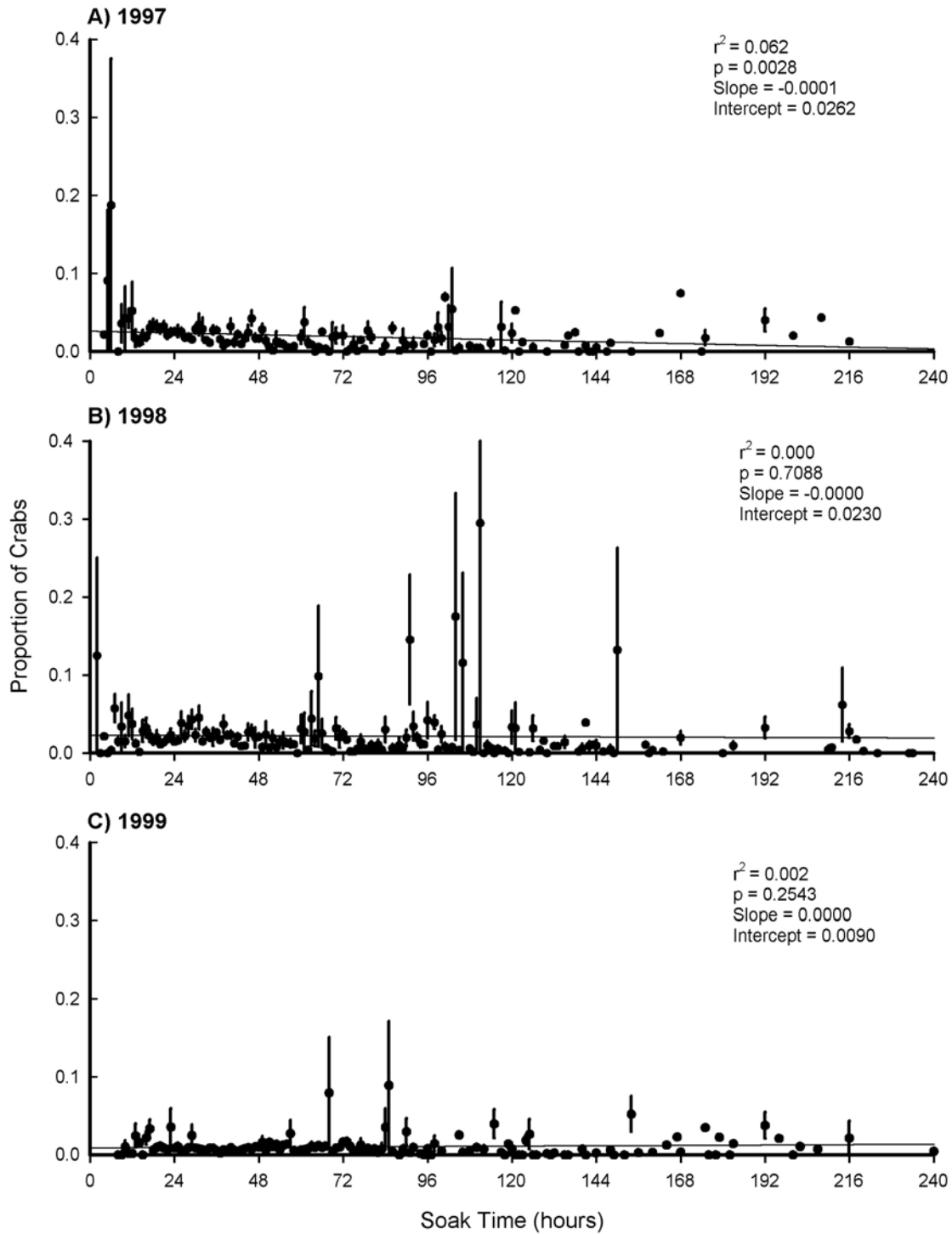


Figure 11. The mean (\pm standard error) proportion of snow crab sublegal males in pots with various soak times for 1997 (A), 1998 (B), and 1999 (C). The r^2 value, p-value, slope, and intercept are given for each year.

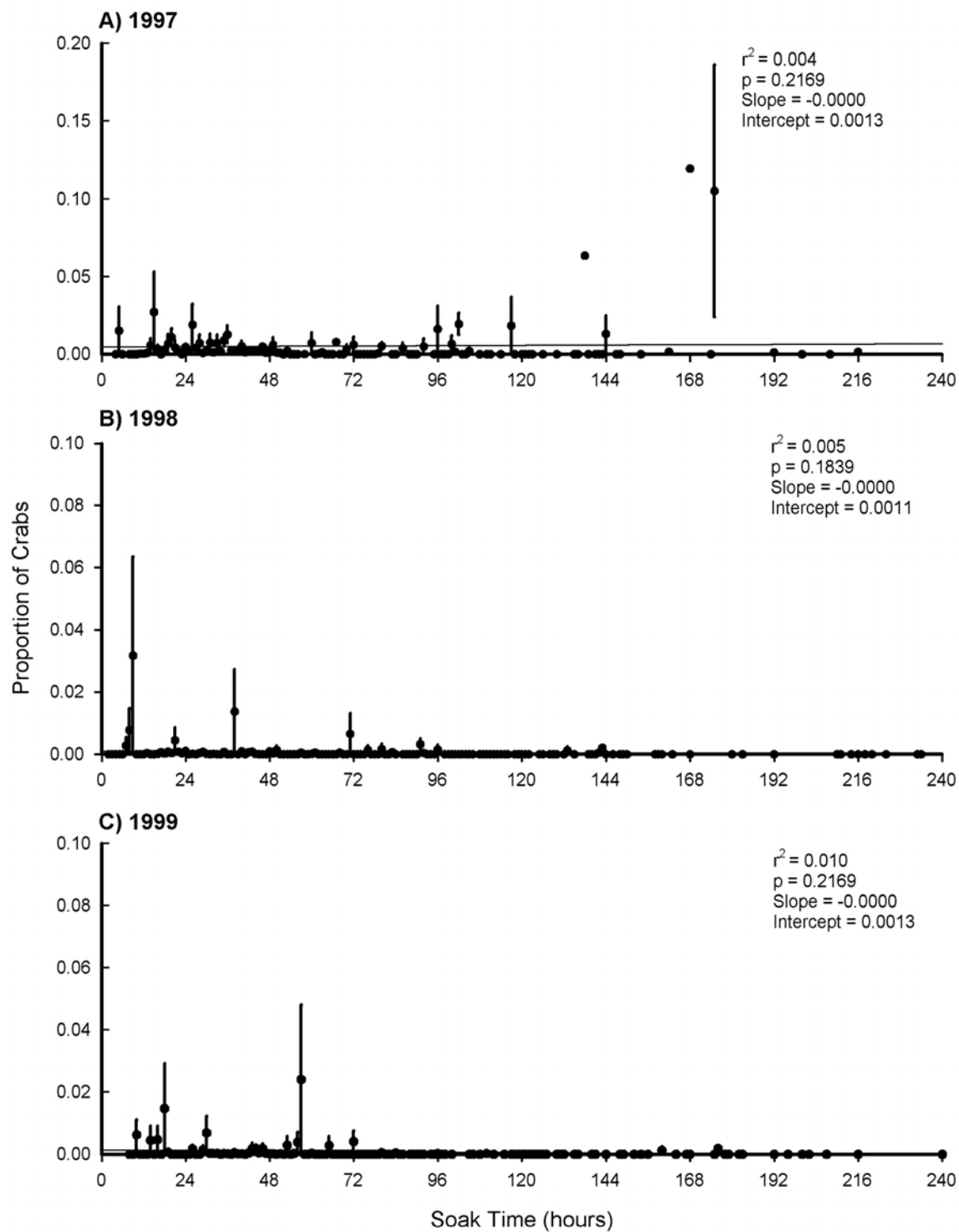


Figure 12. The mean (\pm standard error) proportion of snow crab females in pots with various soak times for 1997 (A), 1998 (B), and 1999 (C). The r^2 value, p-value, slope, and intercept are given for each year.

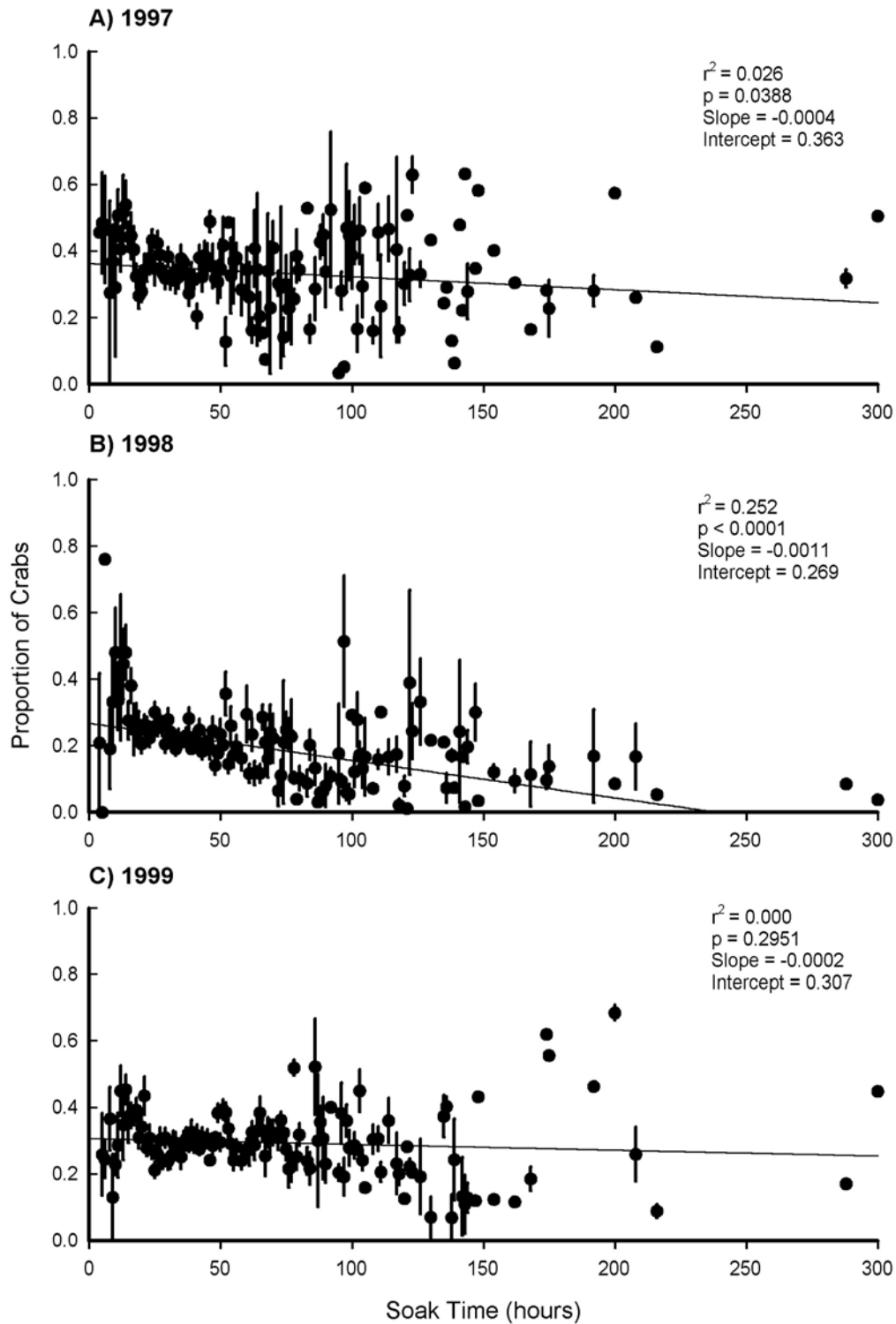


Figure13. The mean (\pm standard error) proportion of snow crabs caught that were discarded legal males in 1997 (A), 1998 (B), and 1999 (C). The r^2 value, p-value, slope, and intercept are given for each year.

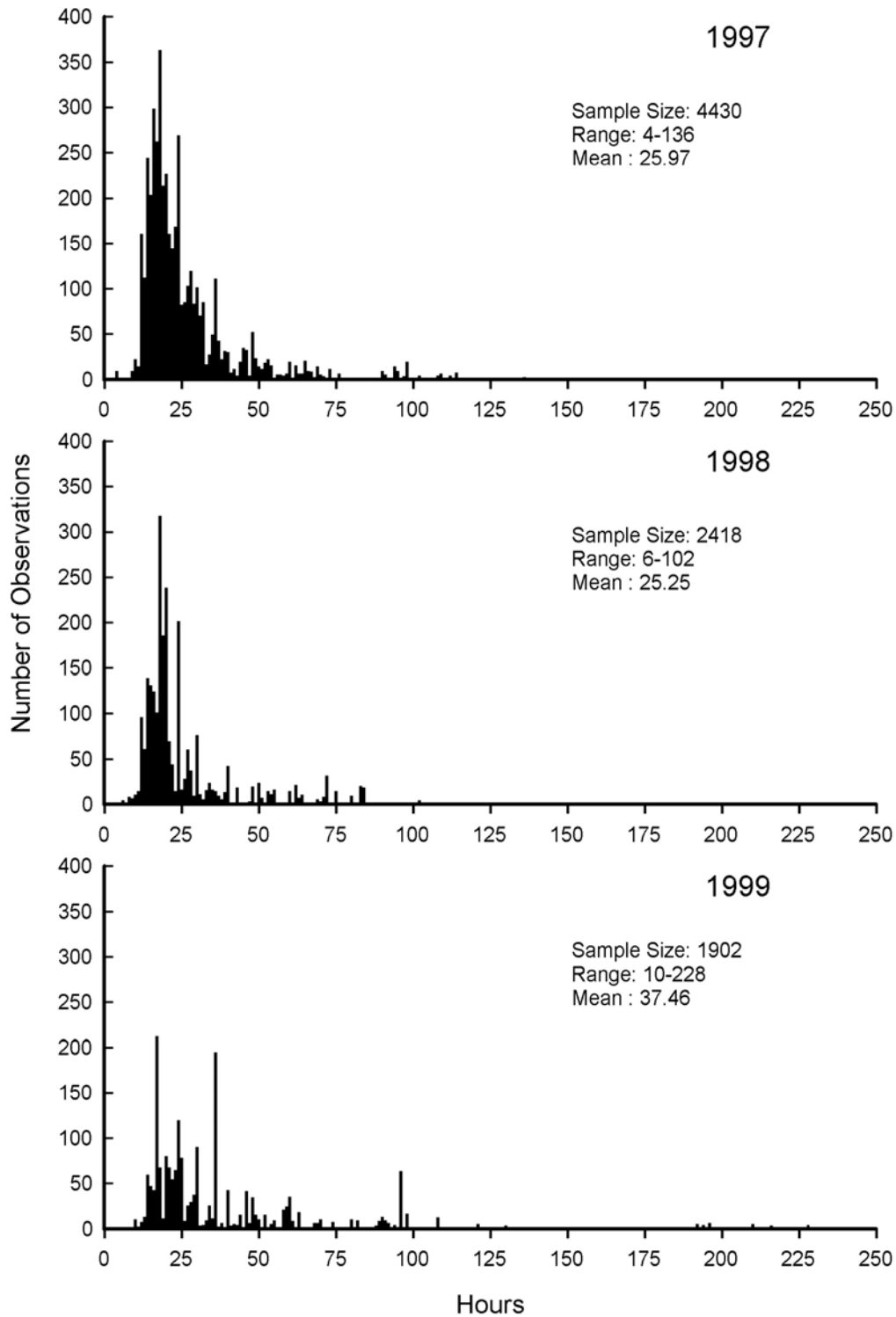


Figure 14. The number of pots observed for various soak times in the Bering Sea hair crab fishery for 1997, 1998, and 1999. The sample size, range, and mean are also given for each year.

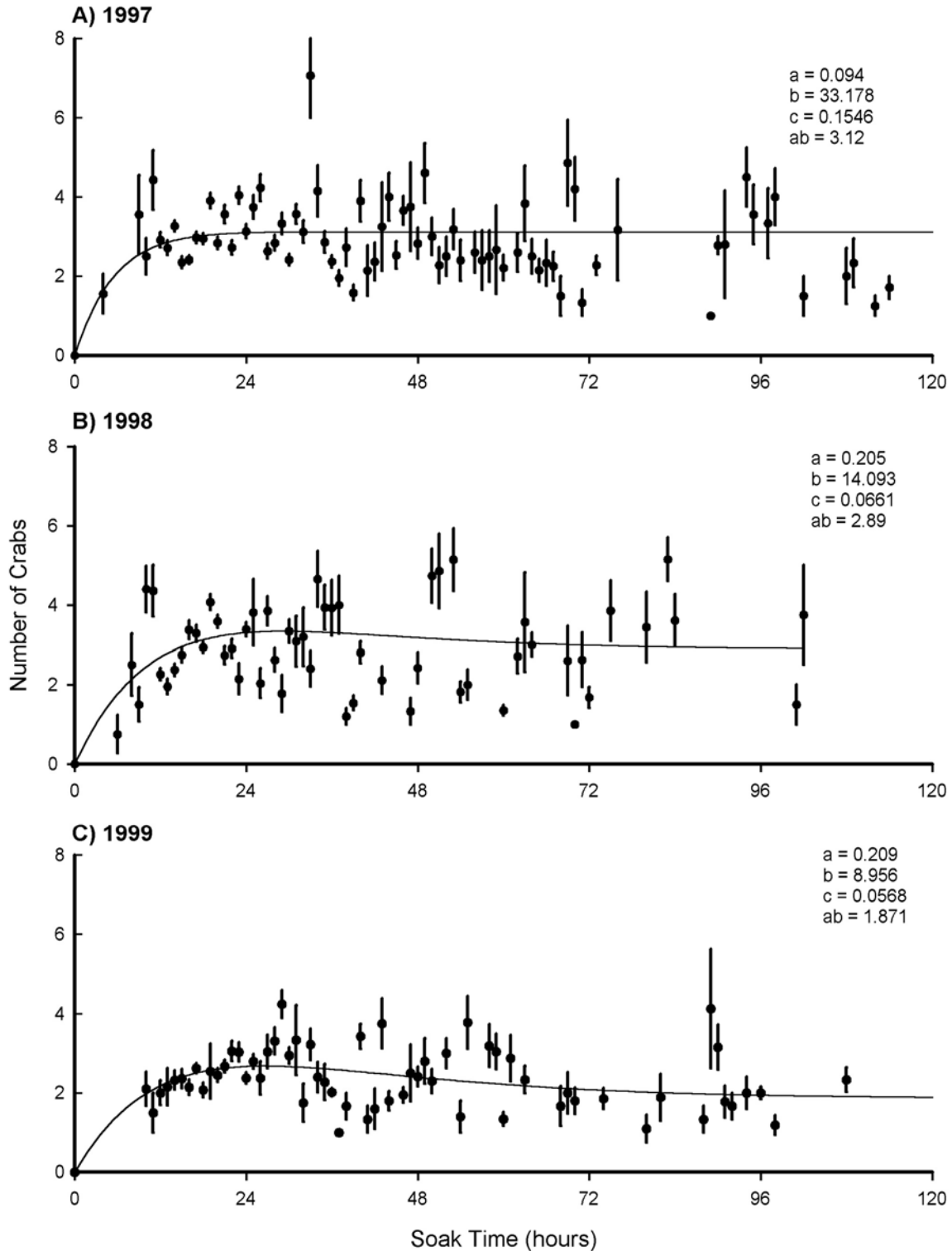


Figure 15. The mean (\pm standard error) total catch per pot of hair crabs with various soak times for 1997 (A), 1998 (B), and 1999 (C). The fitted Zhou-Shirley model parameters are given for each year.

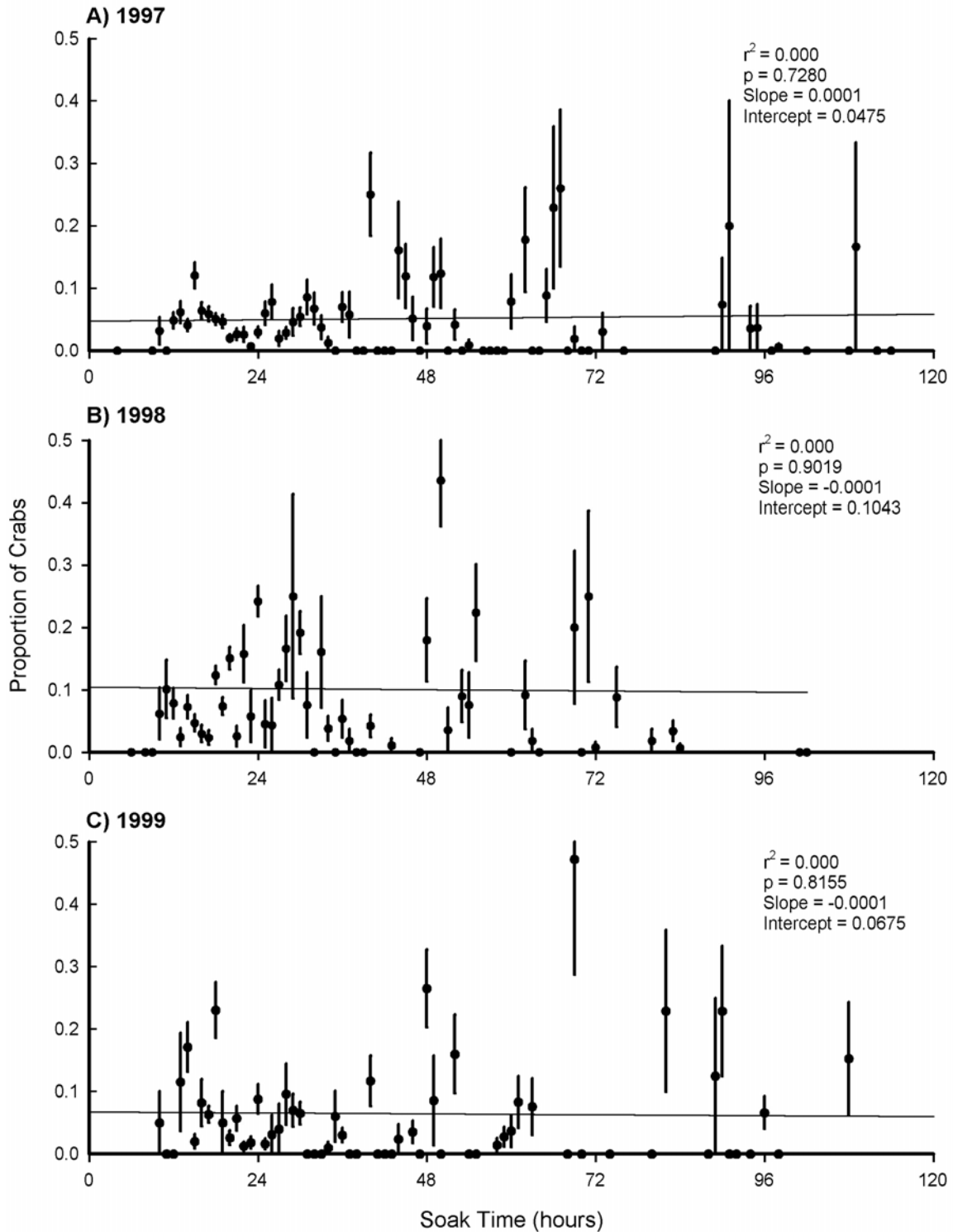


Figure 16. The mean (\pm standard error) proportion of hair crab sublegal males in pots with various soak times for 1997 (A), 1998 (B), and 1999 (C). The r^2 value, p-value, slope, and intercept are given for each year.

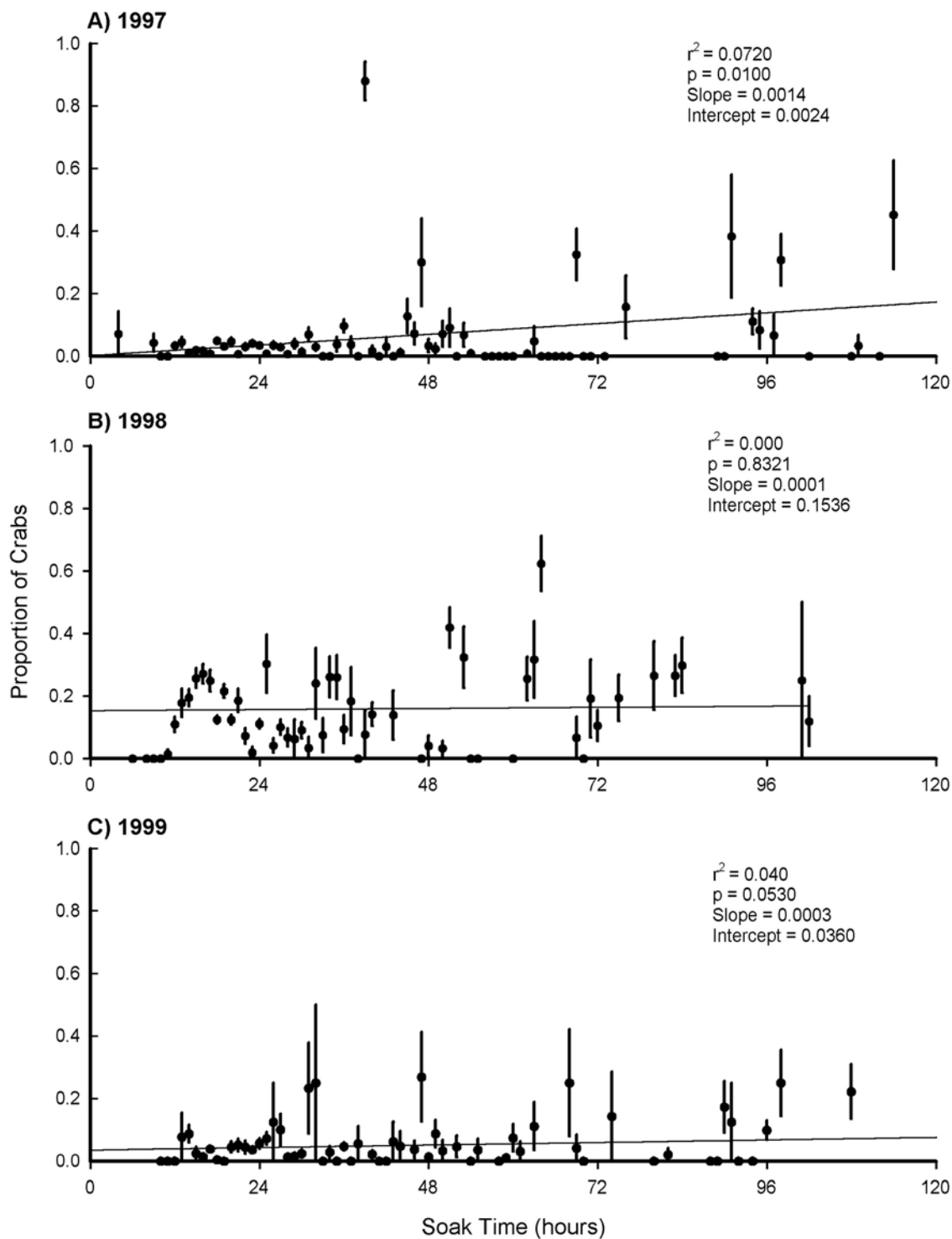


Figure 17. The mean (\pm standard error) proportion of hair crab females in pots with various soak times for 1997 (A), 1998 (B), and 1999 (C). The r^2 value, p-value, slope, and intercept are given for each year.

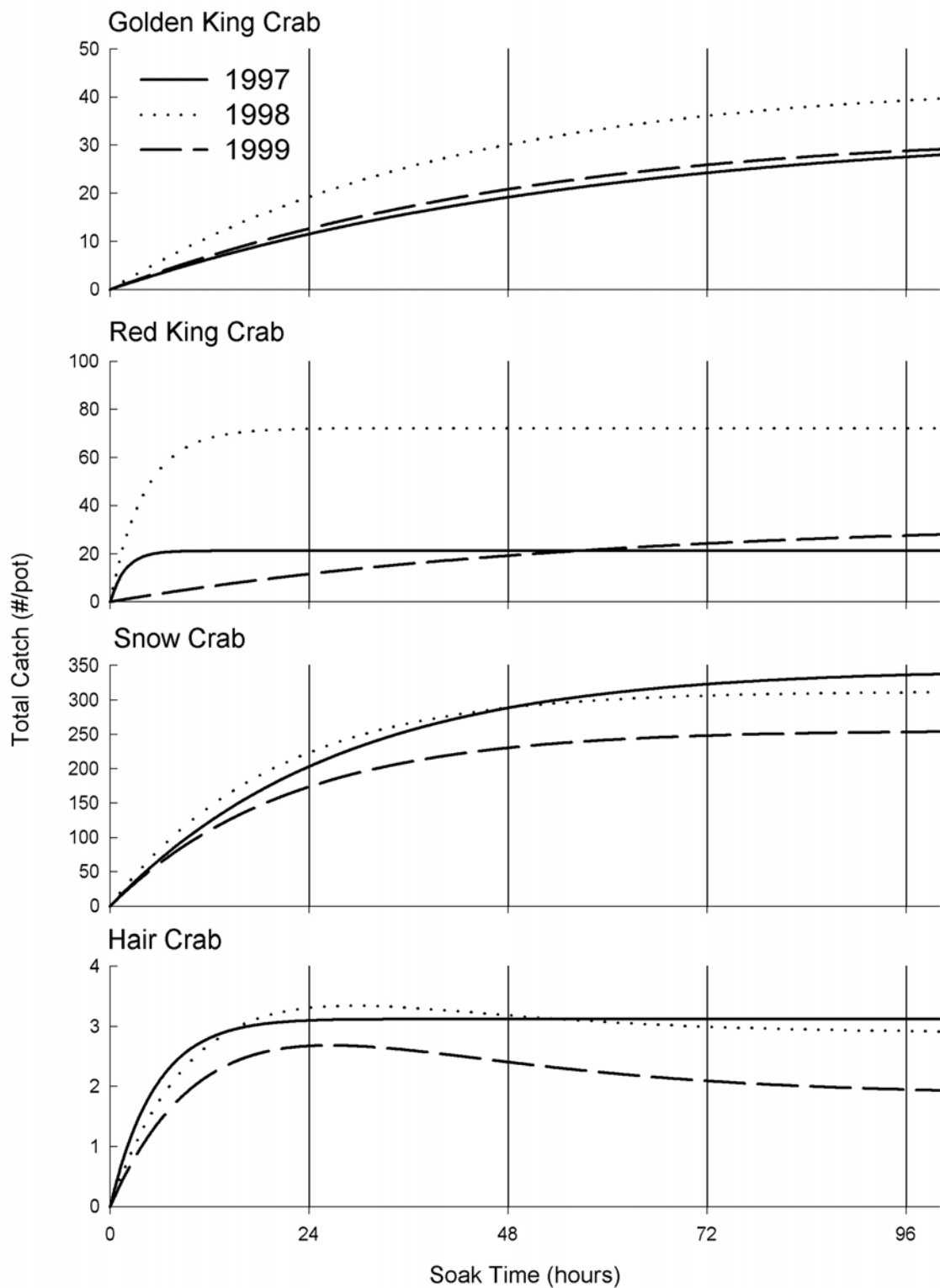


Figure 18. The fitted models for each of three years of the four of the crab fisheries investigated.

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